

REPORT OF ADDITIONAL HYDROGEOLOGIC INVESTIGATIONS

PROPOSED BIG TIMBER LANDFILL SITE

BIG TIMBER, MONTANA

Prepared for:

City of Big Timber  
Big Timber, Montana

**REPORT OF ADDITIONAL  
HYDROGEOLOGIC INVESTIGATIONS  
PROPOSED BIG TIMBER LANDFILL SITE  
BIG TIMBER, MONTANA**

Prepared By:

Chester-Northern, Inc.  
1610 "B" Street  
P. O. Box 4599  
Helena, Montana 59604

August 2, 1990



## TABLE OF CONTENTS

### REPORT OF ADDITIONAL HYDROGEOLOGIC INVESTIGATIONS

#### PROPOSED BIG TIMBER LANDFILL SITE

#### BIG TIMBER, MONTANA

#### 1.0 INTRODUCTION

#### 2.0 DATA COLLECTION ACTIVITIES

##### 2.1 TEST BORING AND MONITORING WELL INSTALLATION

##### 2.2 WATER LEVEL MEASUREMENTS

##### 2.3 AQUIFER TESTS

Prepared for:

#### 3.0 DATA ANALYSIS

##### 3.1 GROUNDWATER

City of Big Timber  
Big Timber, Montana

##### 3.2 AQUIFER PERMEABILITY

#### 4.0 SUMMARY

#### 5.0 REFERENCES CITED

Prepared By:

Chen-Northern, Inc.  
1610 "B" Street  
P. O. Box 4699  
Helena, Montana 59604

August 3, 1990

# REPORT OF ADDITIONAL HYDROLOGIC INVESTIGATIONS

## EMERSON BIG TIMBER LANDFILL SITE

### BIG TIMBER, MONTANA

Prepared by

City of Big Timber  
Big Timber, Montana

Prepared by

Consulting Engineer  
1610 W. 10th St.  
P.O. Box 1000  
Helena, Montana 59601

August 1, 1988

## TABLE OF CONTENTS

|                                                  | Page |
|--------------------------------------------------|------|
| 1.0 INTRODUCTION                                 | 1    |
| 2.0 DATA COLLECTION ACTIVITIES                   | 1    |
| 2.1 TEST BORING AND MONITORING WELL INSTALLATION | 3    |
| 2.2 WATER LEVEL MEASUREMENTS                     | 5    |
| 2.3 AQUIFER TESTS                                | 5    |
| 3.0 DATA ANALYSIS                                | 6    |
| 3.1 GROUNDWATER OCCURRENCE                       | 6    |
| 3.2 AQUIFER PERMEABILITY                         | 7    |
| 4.0 SUMMARY                                      | 9    |
| 5.0 REFERENCES CITED                             | 10   |

### 2.0 DATA COLLECTION ACTIVITIES

To collect additional data requested by the Solid and Hazardous Waste Bureau, two borings were drilled at the potential landfill site (Figure 1). Subsurface materials encountered were logged, sampled, and water-bearing zones were identified. Each of the two new borings were completed as monitoring wells. Slug tests were performed on each well to determine hydraulic characteristics of water-bearing zones encountered. Water levels were measured in all site monitoring wells and a revised map of the potentiometric surface at the site was developed.



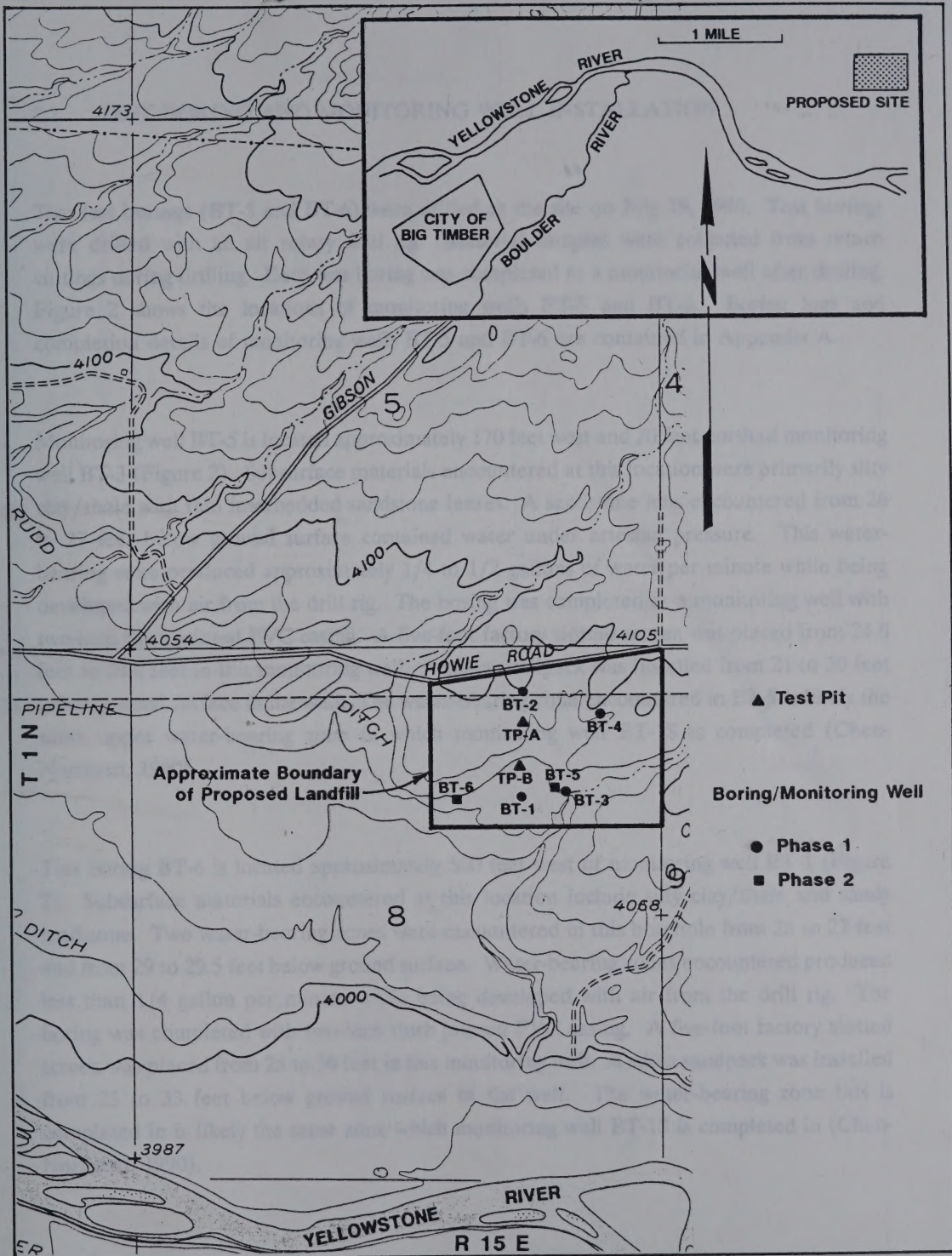
## 1.0 INTRODUCTION

This report presents additional hydrogeologic information collected at the proposed Big Timber landfill site. Additional site hydrogeologic information was requested by the State of Montana, Department of Health and Environmental Sciences, Solid and Hazardous Waste Bureau after their review of Big Timber's landfill license application for the site. Additional information requested by the Solid and Hazardous Waste Bureau included determination of the depth of groundwater-bearing zones near proposed trench locations, additional lithologic information, and in-situ hydrogeologic tests of water-bearing zones. Information presented in this report is intended to fulfill requested data needs and supplement hydrogeologic and subsurface material information contained in the Hydrogeologic Investigation Report (Chen-Northern, 1990) contained in the landfill application.

## 2.0 DATA COLLECTION ACTIVITIES

To collect additional data requested by the Solid and Hazardous Waste Bureau, two borings were drilled at the potential landfill site (Figure 1). Subsurface materials encountered were logged, sampled, and water-bearing zones were identified. Each of the two new borings were completed as monitoring wells. Slug tests were performed on each well to determine hydraulic characteristics of water-bearing zones encountered. Water levels were measured in all site monitoring wells and a revised map of the potentiometric surface at the site was developed.





Proposed Big Timber Landfill Site

FIGURE 1



## 2.1 TEST BORING AND MONITORING WELL INSTALLATION

Two test borings (BT-5 and BT-6) were drilled at the site on July 19, 1990. Test borings were drilled with an air rotary drill rig. Material samples were collected from return cuttings during drilling. Each test boring was completed as a monitoring well after drilling. Figure 2 shows the locations of monitoring wells BT-5 and BT-6. Boring logs and completion details of monitoring wells BT-5 and BT-6 are contained in Appendix A.

Monitoring well BT-5 is located approximately 170 feet west and 20 feet north of monitoring well BT-3 (Figure 2). Subsurface materials encountered at this location were primarily silty clay/shale with thin interbedded sandstone lenses. A sandstone lens encountered from 26 to 27 feet below ground surface contained water under artesian pressure. This water-bearing zone produced approximately 1/4 to 1/2 gallons of water per minute while being developed with air from the drill rig. The boring was completed as a monitoring well with two-inch flush jointed PVC casing. A five-foot factory slotted screen was placed from 24.0 feet to 29.0 feet in this monitoring well. A silica sandpack was installed from 21 to 30 feet below ground surface in the well. The water-bearing zone encountered in BT-5 is likely the same upper water-bearing zone in which monitoring well BT-1S is completed (Chen-Northern, 1990).

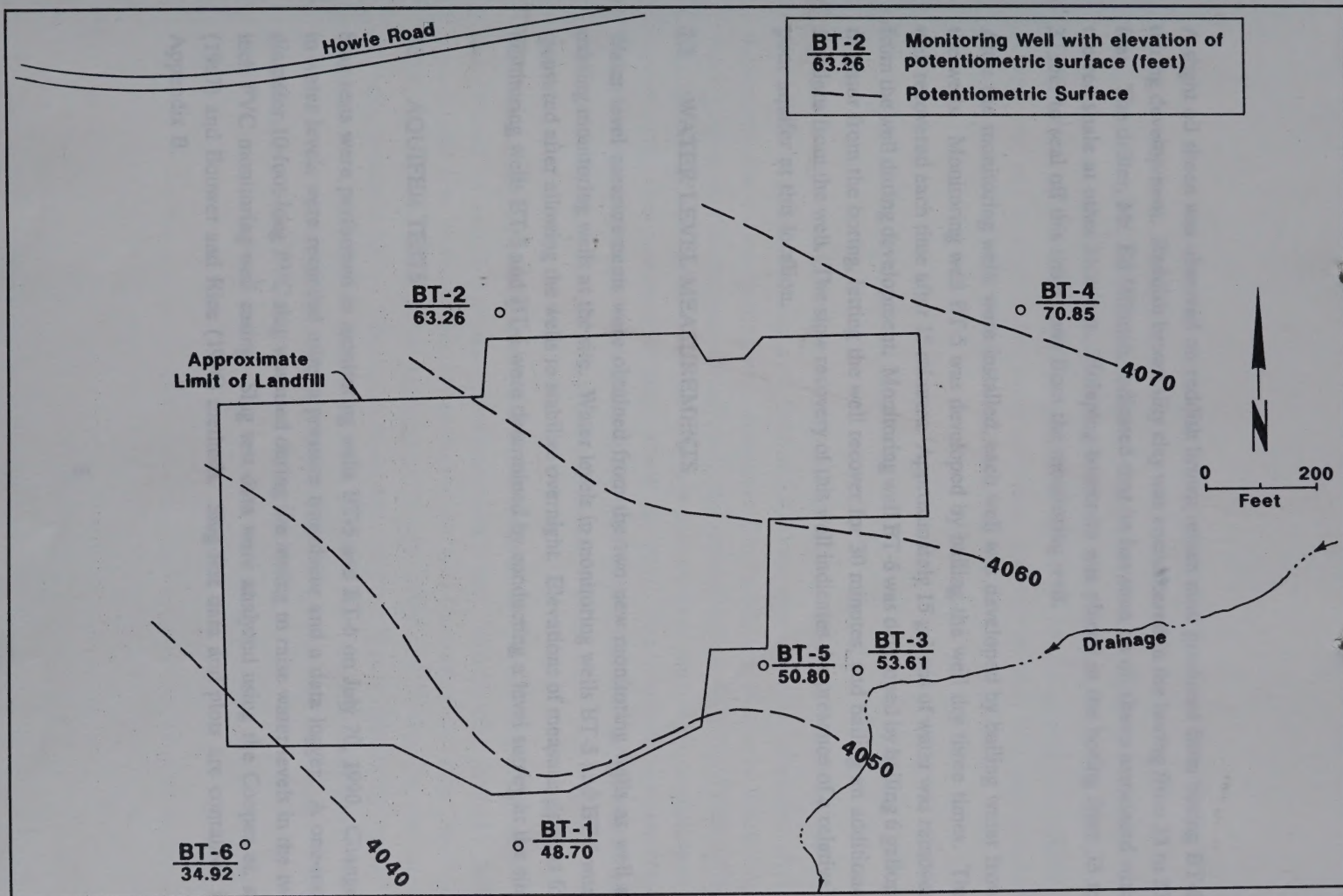
Test boring BT-6 is located approximately 500 feet west of monitoring well BT-1 (Figure 2). Subsurface materials encountered at this location include silty clay/shale and sandy mudstone. Two water-bearing zones were encountered in this borehole from 26 to 27 feet and from 29 to 29.5 feet below ground surface. Water-bearing zones encountered produced less than 1/4 gallon per minute while being developed with air from the drill rig. The boring was completed with two-inch flush jointed PVC casing. A five-foot factory slotted screen was placed from 25 to 30 feet in this monitoring well. A silica sandpack was installed from 23 to 33 feet below ground surface in the well. The water-bearing zone this is completed in is likely the same zone which monitoring well BT-1S is completed in (Chen-Northern, 1990).

## 2.1. TEST BORING AND MONITORING WELL INSTALLATION

Two test borings (BT-2 and BT-3) were drilled at the site on July 19, 1990. Test borings were drilled with an air rotary drill rig. Material samples were collected from return cuttings during drilling. Back test boring was completed as a monitoring well after drilling. Figure 2 shows the locations of monitoring wells BT-2 and BT-3. Boring logs and completion details of monitoring wells BT-2 and BT-3 are contained in Appendix A.

Monitoring well BT-2 is located approximately 170 feet west and 30 feet north of monitoring well BT-3 (Figure 2). Subsurface materials encountered at this location were primarily silty clay/shale with thin interbedded sandstone lenses. A sandstone lens encountered from 25 to 45 feet below ground surface contained water under static pressure. This water-bearing zone produced approximately 1 1/2 to 2 gallons of water per minute while being developed with air from the drill rig. The boring was completed as a monitoring well with two-inch flush jointed PVC casing. A five-foot factory slotted screen was placed from 24 to 26 feet in the monitoring well. A silted sandpack was installed from 21 to 30 feet below ground surface in the well. The water-bearing zone encountered in BT-2 is likely the same zone which water-bearing zone in which monitoring well BT-1 is completed (Chen-Norbert, 1990).

Test boring BT-3 is located approximately 300 feet west of monitoring well BT-1 (Figure 2). Subsurface materials encountered at this location include silty clay/shale and sandstone. Two water-bearing zones were encountered in this borehole from 25 to 33 feet and from 39 to 49 feet below ground surface. Water-bearing zones encountered produced less than 1 1/2 gallons per minute while being developed with air from the drill rig. The boring was completed with two-inch flush jointed PVC casing. A five-foot factory slotted screen was placed from 21 to 30 feet in the monitoring well. A silted sandpack was installed from 23 to 25 feet below ground surface in the well. The water-bearing zone this is completed in (Chen-Norbert, 1990).



July 19, 20, 1990  
Potentiometric Surface Map  
Proposed Big Timber Landfill  
FIGURE 2



A slight oil sheen was observed on reddish brown return mud produced from boring BT-6 during development. Reddish brown silty clay was encountered in the boring from 33 to 37 feet. The driller, Mr. Ed Hillman, indicated that he has seen an oil sheen associated with the red shale at other locations. Holeplug bentonite was placed in the boring from 33 to 37 feet to seal off this shale zone from the monitoring well.

After the monitoring wells were installed, each well was developed by bailing water from the wells. Monitoring well BT-5 was developed by bailing the well dry three times. The well recovered each time after 15 minutes. Approximately 15 gallons of water was removed from the well during development. Monitoring well BT-6 was developed by bailing 6 gallons of water from the boring, letting the well recover for 30 minutes, and bailing an additional 5 gallons from the well. The slow recovery of this well indicates the presence of a relatively poor aquifer at this location.

## 2.2 WATER LEVEL MEASUREMENTS

Water level measurements were obtained from the two new monitoring wells as well as existing monitoring wells at the site. Water levels in monitoring wells BT-5 and BT-6 were measured after allowing the wells to stabilize overnight. Elevations of measuring points for monitoring wells BT-5 and BT-6 were determined by conducting a level survey at the site.

## 2.3 AQUIFER TESTS

Slug tests were performed in monitoring wells BT-5 and BT-6 on July 20, 1990. Changes in water levels were recorded using a pressure transducer and a data logger. A one-inch diameter 10-foot-long PVC slug was used during the testing to raise water levels in the two inch PVC monitoring well casing. Slug test data were analyzed using the Cooper et. al. (1967) and Bouwer and Rice (1976) methods. Slug test data and plots are contained in Appendix B.

A slight oil sheen was observed on reddish brown retorts mud produced from boring BT-5 during development. Reddish brown silty clay was encountered in the boring from 33 to 37 feet. The driller, Mr. Ed Hillman, indicated that he has seen an oil sheen associated with the red shale at other locations. Flowing bentonite was placed in the boring from 33 to 37 feet to seal off the shale zone from the adjoining well.

After the monitoring wells were installed, each well was developed by bailing water from the wells. Monitoring well BT-3 was developed by bailing the well six times. The well recovered each time after 15 minutes. Approximately 15 gallons of water was removed from the well during development. Monitoring well BT-6 was developed by bailing 6 gallons of water from the boring, bailing the well recover for 30 minutes and bailing an additional 5 gallons from the well. The slow recovery of this well indicates the presence of a relatively poor aquifer at this location.

## 12. WATER LEVEL MEASUREMENTS

Water level measurements were obtained from the two new monitoring wells as well as existing monitoring wells at the site. Water levels in monitoring wells BT-3 and BT-6 were measured after allowing the wells to stabilize overnight. Elevations of measurement points for monitoring wells BT-3 and BT-6 were determined by conducting a level survey at the site.

## 13. ADDITIONAL TESTS

Slug tests were performed in monitoring wells BT-3 and BT-6 on July 20, 1990. Charges in water levels were recorded using a pressure transducer and a data logger. A one-inch diameter 10-foot-long PVC slug was used during the testing to raise water levels in the two test PVC monitoring well casing. Slug test data were analyzed using the Cooper et al. (1967) and Bouwer and Rice (1976) methods. Slug test data and plots are contained in Appendix B.

### 3.0 DATA ANALYSIS

Data collected during this second phase of the investigation were used in conjunction with previously collected data (Chen-Northern, 1990) to further evaluate the hydrogeological and subsurface materials present at the proposed landfill site. A revised potentiometric surface contour map was developed using water level data. Aquifer test data were used to further evaluate hydraulics of the potential landfill site.

#### 3.1 GROUNDWATER OCCURRENCE

Groundwater encountered in the two additional monitoring wells BT-5 and BT-6 is confined. Static water levels in monitoring wells BT-5 and BT-6 are approximately 10 feet and 5.5 feet respectively above water-bearing zones encountered in the borings. Similar confined water-bearing zones were encountered during installation of monitoring wells BT-1, BT-2, and BT-4 at the site (Chen-Northern, 1990). Figure 2 is a contour map of the potentiometric surface at the site measured on July 19 and 20, 1990. The potentiometric surface is constructed using the static water levels in the uppermost water bearing zone at the site. Static water levels measured at the site are contained in Table 1.

Examination of the potentiometric surface map indicates that the direction of groundwater flow beneath the landfill is generally northeast to southwest. This direction is similar to the groundwater flow direction determined during the initial investigation (Chen-Northern, 1990). Unconfined groundwater encountered in monitoring well BT-3 has a static water level approximately 2.8 feet higher than the potentiometric surface in monitoring well BT-5. Recharge for this unconfined groundwater may be from alluvium in the small stream valley north and west of the site or possibly from upward leakage from the underlying confined groundwater systems.

## 2.0 DATA ANALYSIS

Data collected during the second phase of the investigation were used in conjunction with previously collected data (Chen-Northrup, 1990) to further evaluate the hydrogeological and geotechnical conditions present at the proposed landfill site. A revised potentiometric surface contour map was developed using water level data. Another test data were used to further evaluate hydraulic of the potential landfill site.

## 2.1 GROUNDWATER OCCURRENCE

Groundwater encountered in the two additional monitoring wells BT-3 and BT-4 is described. Static water levels in monitoring wells BT-3 and BT-4 are approximately 10 feet and 2.5 feet, respectively above water-bearing zones encountered in the borehole. Similar ground water bearing zones were encountered during installation of monitoring wells BT-1, BT-2, and BT-5 at the site (Chen-Northrup, 1990). Figure 2 is a contour map of the potentiometric surface at the two measured on July 19 and 20, 1990. The potentiometric surface is depicted along the static water levels in the uppermost water bearing zone of the site. Static water levels measured at the site are presented in Table 1.

Examination of the potentiometric surface map indicates that the direction of groundwater flow towards the landfill is generally northeast to southwest. This direction is similar to the groundwater flow direction determined during the initial investigation (Chen-Northrup, 1990). Unconfined groundwater encountered in monitoring well BT-3 has a static water level approximately 1.5 feet higher than the potentiometric surface in monitoring well BT-5. Recharge for the unconfined groundwater may be from infiltration in the small stream valley north and west of the site or possibly from upward leakage from the underlying confined groundwater system.

**TABLE 1**  
**STATIC WATER LEVELS**  
**PROPOSED BIG TIMBER LANDFILL SITE**

| Location | SWL<br>(Ft. Below M.P.) |         | Elevation<br>(feet above mean sea level) |                                               |         |
|----------|-------------------------|---------|------------------------------------------|-----------------------------------------------|---------|
|          | 9/8/89                  | 7/19/90 | Measuring<br>Point                       | Potentiometric Surface<br>9/8/89      7/19/90 |         |
| BT-1S    | 18.42                   | 19.08   | 4067.78                                  | 4049.4                                        | 4048.70 |
| BT-1D    | 18.36                   | 19.23   | 4067.78                                  | 4049.4                                        | 4048.55 |
| BT-2     | 23.64                   | 27.29   | 4090.55                                  | 4066.9                                        | 4063.26 |
| BT-3     | 14.67                   | 15.70   | 4069.31                                  | 4054.6                                        | 4053.61 |
| BT-4     | 16.62                   | 16.79   | 4087.64                                  | 4071.0                                        | 4070.85 |
| BT-5     | NA                      | 18.45   | 4069.25                                  | NA                                            | 4050.80 |
| BT-6     | NA                      | 22.65   | 4057.57                                  | NA                                            | 4034.92 |

Note: NA = Not Applicable

### 3.2 AQUIFER PERMEABILITY

Slug tests were performed on monitoring wells BT-5 and BT-6 to determine aquifer characteristics of the upper water-bearing zone. Test results were analyzed using the Cooper et. al. (1967) and Bouwer and Rice (1976) methods. The Cooper method is applicable for confined aquifers and the Bouwer and Rice method is applicable for confined and unconfined aquifers (Bouwer, 1989). Table 2 summarizes aquifer storage, transmissivity, and hydraulic conductivity values determined using these methods. Aquifer parameters

TABLE 1  
STATIC WATER LEVELS  
PROPOSED BIG TIMBER LANDFILL SITE

| Location | SWL<br>(ft Below M.F.) |         | Elevation<br>(feet above mean sea level) |                                          |
|----------|------------------------|---------|------------------------------------------|------------------------------------------|
|          | 9/8/89                 | 7/19/90 | Measuring<br>Point                       | Potentiometric Surface<br>9/8/89 7/19/90 |
| BT-12    | 18.45                  | 18.05   | 4067.78                                  | 4069.70                                  |
| BT-10    | 18.36                  | 19.33   | 4067.78                                  | 4068.32                                  |
| BT-8     | 22.64                  | 22.29   | 4060.75                                  | 4063.26                                  |
| BT-7     | 18.67                  | 18.70   | 4066.71                                  | 4067.61                                  |
| BT-6     | 18.62                  | 18.79   | 4067.64                                  | 4070.82                                  |
| BT-5     | NA                     | 18.42   | 4066.72                                  | 4070.80                                  |
| BT-6     | NA                     | 22.65   | 4067.75                                  | 4074.92                                  |

Note: NA = Not Applicable

## 3.2. AQUIFER PERMEABILITY

Slug tests were performed on monitoring wells BT-5 and BT-6 to determine aquifer characteristics of the upper water-bearing zone. Test results were analyzed using the Cooper et al. (1967) and Bouwer and Rice (1976) methods. The Cooper method is applicable for confined aquifers and the Bouwer and Rice method is applicable for confined and unconfined aquifers (Bouwer, 1989). Table 2 summarizes aquifer storage, transmissivity, and hydraulic conductivity values determined using these methods. Aquifer parameters

determined for the shallow and deep water-bearing zones in monitoring wells BT-1S and BT-1D during the initial hydrogeologic investigation (Chen-Northern, 1990) are also contained in Table 2.

**TABLE 2**  
**AQUIFER CHARACTERISTICS**  
**PROPOSED BIG TIMBER LANDFILL SITE**

| Well  | Test Method     | Analysis Method    |                             |                      |                             |                      |
|-------|-----------------|--------------------|-----------------------------|----------------------|-----------------------------|----------------------|
|       |                 | Cooper et.al.,1967 |                             |                      | Bouwer & Rice, 1976         |                      |
|       |                 | S                  | T<br>(cm <sup>2</sup> /sec) | K<br>(cm/sec)        | T<br>(cm <sup>2</sup> /sec) | K<br>(cm/sec)        |
| BT-1S | Bailer-Recovery |                    |                             |                      | $9.1 \times 10^{-2}$        | $3.0 \times 10^{-4}$ |
| BT-1D | Bailer-Recovery |                    |                             |                      | $7.0 \times 10^{-2}$        | $2.4 \times 10^{-4}$ |
| BT-5  | Slug-in         | 0.001              | $6.6 \times 10^{-2}$        | $2.4 \times 10^{-4}$ | $4.0 \times 10^{-2}$        | $1.5 \times 10^{-4}$ |
| BT-6  | Slug-in         | 0.0005             | $2.2 \times 10^{-4}$        | $9.5 \times 10^{-5}$ | $3.0 \times 10^{-4}$        | $9.9 \times 10^{-7}$ |

The calculated hydraulic conductivity of the water-bearing zone in BT-5 ranges from  $1.5 \times 10^{-4}$  cm/sec to  $2.4 \times 10^{-4}$  cm/sec. This is similar to hydraulic conductivities calculated for water-bearing zones in monitoring wells BT-1S and BT-1D (Table 2). The calculated hydraulic conductivity of the water-bearing zone in BT-6 ranges from  $7.1 \times 10^{-7}$  cm/sec to  $9.9 \times 10^{-7}$  cm/sec. This hydraulic conductivity is relatively low and significantly lower than the hydraulic conductivity of the water-bearing zones encountered in BT-1S, BT-1D, and BT-5. All hydraulic conductivity values determined are typical of fractured rocks and sandstone and are in the middle to low range of hydraulic conductivities of geologic materials (Freeze and Cherry, 1979).

determined for the shallow and deep water-bearing zones in monitoring wells BT-12 and BT-1D during the initial hydrogeologic investigation (Cowan-Nordstrom, 1990) are also presented in Table 1.

TABLE 1  
AQUIFER CHARACTERISTICS  
PROPOSED BIG TIMBER LANDFILL SITE

| Well  | Test Method       | Aquifer Method         |                        |                      |                      |
|-------|-------------------|------------------------|------------------------|----------------------|----------------------|
|       |                   | Cooper et al., 1967    |                        | Bower & Rice, 1978   |                      |
|       |                   | S                      | T                      | K                    | E                    |
|       |                   | (cm <sup>2</sup> /sec) | (cm <sup>2</sup> /sec) | (cm/sec)             | (cm/sec)             |
| BT-12 | Recovery-Recovery |                        |                        | $2.1 \times 10^{-5}$ | $2.2 \times 10^{-5}$ |
| BT-1D | Recovery-Recovery |                        |                        | $7.0 \times 10^{-5}$ | $2.4 \times 10^{-5}$ |
| BT-3  | Slug-in           | 0.001                  | $8.6 \times 10^{-5}$   | $2.4 \times 10^{-4}$ | $1.2 \times 10^{-4}$ |
| BT-4  | Slug-in           | 0.002                  | $2.2 \times 10^{-4}$   | $9.2 \times 10^{-5}$ | $9.9 \times 10^{-5}$ |

The calculated hydraulic conductivity of the water-bearing zone in BT-3 ranges from  $1.2 \times 10^{-4}$  cm/sec to  $2.4 \times 10^{-4}$  cm/sec. This is similar to hydraulic conductivities calculated for water-bearing zones in monitoring wells BT-12 and BT-1D (Table 1). The calculated hydraulic conductivity of the water-bearing zone in BT-4 ranges from  $7.1 \times 10^{-5}$  cm/sec to  $9.9 \times 10^{-5}$  cm/sec. This hydraulic conductivity is relatively low and significantly lower than the hydraulic conductivity of the water-bearing zones encountered in BT-12, BT-1D, and BT-3. All hydraulic conductivity values determined are typical of fractured rocks and sandstones and are in the middle to low range of hydraulic conductivities of geologic materials (Peters and Cherry, 1979).

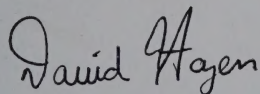
#### 4.0 SUMMARY

Additional hydrogeologic and subsurface material investigative activities completed at the proposed Big Timber landfill site indicate that the southern portion of the area proposed to be landfilled is underlain by silty clay/shale strata containing interbedded sandstone and sandy mudstone layers. The uppermost water-bearing zone encountered near the southern part of the site is a sandstone which is present at a depth of approximately 26 feet below ground surface. This water-bearing sandstone contains artesian water with a potentiometric head of 5.5 to 10 feet.

The maximum trench depth proposed for the landfill at the southern edge of the landfill site is 10 feet. The minimum separation between the bottom of the landfill and the first water-bearing zone would thus be 16 feet.

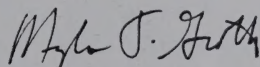
Unconfined groundwater encountered in monitoring well BT-3 appears to originate in the small drainage located north and west of the site or from upward leakage from underlying confined groundwater systems. Hydraulic conductivities of water-bearing sandstones underlying the site range from  $3.0 \times 10^{-4}$  cm/sec to  $7.1 \times 10^{-7}$  cm/sec.

Prepared by:



David Hazen P.G.  
Geological Engineer/Hydrogeologist

Reviewed by:



Myles Grotbo  
Senior Hydrogeologist

# 10 SUMMARY

Additional hydrologic and subsurface material investigative activities completed at the proposed Big Timber landfill site indicate that the southern portion of the area proposed to be landfilled is underlain by silty clay/siltstone containing interbedded sandstone and sandy mudstone layers. The uppermost water-bearing zone encountered near the northern part of the site is a sandstone which is present at a depth of approximately 35 feet below ground surface. This water-bearing sandstone contains brackish water with a potentiometric head of 2.5 to 10 feet.

The maximum north-south depth proposed for the landfill at the southern edge of the landfill site is 10 feet. The minimum separation between the bottom of the landfill and the first water-bearing zone would thus be 10 feet.

Unconfined groundwater encountered in monitoring well BT-3 appears to originate in the small drainage located north and west of the site or from upward leakage from underlying confined groundwater systems. Hydraulic conductivities of water-bearing sandstones underlying the site range from  $5.0 \times 10^{-4}$  cm/sec to  $1.1 \times 10^{-2}$  cm/sec.

Reviewed by:

*Mr. D. J. ...*

Style: George

Senior Hydrologist

Prepared by:

*David H. ...*

David H. ... P.O.

Geological Engineer/Hydrologist

## 5.0 REFERENCES CITED

- Bouwer, H., 1989. The Bouwer and Rice Slug Test - an Update. Groundwater, Vol. 27, No. 3, pp. 304-309.
- Bouwer, H. and R. C. Rice, 1976. Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research, Vol. 13, June, 1976, pp. 424-428.
- Chen-Northern, 1990. Hydrogeologic Investigation Report, Proposed Big Timber Landfill Site, Big Timber, Montana. Report to the City of Big Timber, January 9, 1990.
- Cooper, H. H. Jr., J. D. Bredehoeft, and I. S. Papadopoulos, 1967. Response of a Finite-diameter Well to an Instantaneous Charge of Water. Water Resources Research, Vol. 3, no. 1, pp. 263-269.
- Freeze, R. A., and J. A. Cherry, 1979. Groundwater. Prentice-Hall, Inc.

# REFERENCES CITED

Bowser, H. 1989. The Bowser and Rice Slug Test - an Update. Groundwater, Vol. 21, No. 2, pp. 304-310.

Bowser, H. and R. C. Rice. 1978. Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research, Vol. 14, June, 1978, pp. 424-428.

Grand National. 1990. Hydrogeologic Investigation Report, Proposed Big Timber Landfill. Big Timber, Montana. Report to the City of Big Timber, January 9, 1990.

Casper, H. R., J. D. Brinkhoff, and L. S. Papadopoulos. 1967. Response of a Finite-diameter Well to an Instantaneous Change of Water. Water Resources Research, Vol. 3, no. 1, pp. 20-26.

Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc.

# CONTINUED WELL LOGS OF THE COMPLETION LOG

WELL NO.                      STATE NY COUNTY Albany TOWN                     

SECTION                      TRACT                      LOCATION                     

DATE                      COMPLETED                      DRILLING COMPANY                      LOGGED BY                     

DRILLING METHOD                      DRILLER                      DRILL FLUID USED                     

TOTAL DEPTH                      TOTAL Casing                      INTERVAL INFORMATION                      DIA. OF CASING                     

DRILLED BY                      Cased by                      ON SCHEDULE                      TYPE OF CASING                     

METHOD OF PERFORATION                      PERFORATION                      PERFORATION                     

WELL INFORMATION CHARACTERISTICS

WELL DEPTH                      DIA. OF CASING                      DIA. OF WELL                     

LOG NO.                      LOG DATE                      LOG TIME                     

WELL NO.                      DATE                      ELEVATION                      WELL DEPTH                     

## APPENDIX A

## BORING AND MONITORING WELL COMPLETION LOGS

| WELL NO. | WELL DEPTH | WELL DEPTH | WELL DEPTH |
|----------|------------|------------|------------|
| 101      | 101        | 101        | 101        |
| 102      | 102        | 102        | 102        |
| 103      | 103        | 103        | 103        |
| 104      | 104        | 104        | 104        |
| 105      | 105        | 105        | 105        |
| 106      | 106        | 106        | 106        |
| 107      | 107        | 107        | 107        |
| 108      | 108        | 108        | 108        |
| 109      | 109        | 109        | 109        |
| 110      | 110        | 110        | 110        |
| 111      | 111        | 111        | 111        |
| 112      | 112        | 112        | 112        |
| 113      | 113        | 113        | 113        |
| 114      | 114        | 114        | 114        |
| 115      | 115        | 115        | 115        |
| 116      | 116        | 116        | 116        |
| 117      | 117        | 117        | 117        |
| 118      | 118        | 118        | 118        |
| 119      | 119        | 119        | 119        |
| 120      | 120        | 120        | 120        |
| 121      | 121        | 121        | 121        |
| 122      | 122        | 122        | 122        |
| 123      | 123        | 123        | 123        |
| 124      | 124        | 124        | 124        |
| 125      | 125        | 125        | 125        |
| 126      | 126        | 126        | 126        |
| 127      | 127        | 127        | 127        |
| 128      | 128        | 128        | 128        |
| 129      | 129        | 129        | 129        |
| 130      | 130        | 130        | 130        |
| 131      | 131        | 131        | 131        |
| 132      | 132        | 132        | 132        |
| 133      | 133        | 133        | 133        |
| 134      | 134        | 134        | 134        |
| 135      | 135        | 135        | 135        |
| 136      | 136        | 136        | 136        |
| 137      | 137        | 137        | 137        |
| 138      | 138        | 138        | 138        |
| 139      | 139        | 139        | 139        |
| 140      | 140        | 140        | 140        |
| 141      | 141        | 141        | 141        |
| 142      | 142        | 142        | 142        |
| 143      | 143        | 143        | 143        |
| 144      | 144        | 144        | 144        |
| 145      | 145        | 145        | 145        |
| 146      | 146        | 146        | 146        |
| 147      | 147        | 147        | 147        |
| 148      | 148        | 148        | 148        |
| 149      | 149        | 149        | 149        |
| 150      | 150        | 150        | 150        |
| 151      | 151        | 151        | 151        |
| 152      | 152        | 152        | 152        |
| 153      | 153        | 153        | 153        |
| 154      | 154        | 154        | 154        |
| 155      | 155        | 155        | 155        |
| 156      | 156        | 156        | 156        |
| 157      | 157        | 157        | 157        |
| 158      | 158        | 158        | 158        |
| 159      | 159        | 159        | 159        |
| 160      | 160        | 160        | 160        |
| 161      | 161        | 161        | 161        |
| 162      | 162        | 162        | 162        |
| 163      | 163        | 163        | 163        |
| 164      | 164        | 164        | 164        |
| 165      | 165        | 165        | 165        |
| 166      | 166        | 166        | 166        |
| 167      | 167        | 167        | 167        |
| 168      | 168        | 168        | 168        |
| 169      | 169        | 169        | 169        |
| 170      | 170        | 170        | 170        |
| 171      | 171        | 171        | 171        |
| 172      | 172        | 172        | 172        |
| 173      | 173        | 173        | 173        |
| 174      | 174        | 174        | 174        |
| 175      | 175        | 175        | 175        |
| 176      | 176        | 176        | 176        |
| 177      | 177        | 177        | 177        |
| 178      | 178        | 178        | 178        |
| 179      | 179        | 179        | 179        |
| 180      | 180        | 180        | 180        |
| 181      | 181        | 181        | 181        |
| 182      | 182        | 182        | 182        |
| 183      | 183        | 183        | 183        |
| 184      | 184        | 184        | 184        |
| 185      | 185        | 185        | 185        |
| 186      | 186        | 186        | 186        |
| 187      | 187        | 187        | 187        |
| 188      | 188        | 188        | 188        |
| 189      | 189        | 189        | 189        |
| 190      | 190        | 190        | 190        |
| 191      | 191        | 191        | 191        |
| 192      | 192        | 192        | 192        |
| 193      | 193        | 193        | 193        |
| 194      | 194        | 194        | 194        |
| 195      | 195        | 195        | 195        |
| 196      | 196        | 196        | 196        |
| 197      | 197        | 197        | 197        |
| 198      | 198        | 198        | 198        |
| 199      | 199        | 199        | 199        |
| 200      | 200        | 200        | 200        |



100

| INTERVAL (FT)<br>below ground<br>surface | LITHOLOGIC DESCRIPTION                        | REMARKS                                              |
|------------------------------------------|-----------------------------------------------|------------------------------------------------------|
| 0-8'                                     | Silt, Clay and Sand, light brown              | dry                                                  |
| 8-10'                                    | Sandstone lense, gray, fine grained           | hard drilling                                        |
| 10-15'                                   | Silty Clay, gray to reddish brown, minor sand | slightly moist                                       |
| 15-16'                                   | Sandstone, light gray brown, medium grained   | dry                                                  |
| 16-19.5'                                 | Silty clay, reddish brown, minor sand         | slightly moist - let sit at 17.5' for 5 minutes, dry |
| 19.5-20'                                 | Sandstone lense                               | dry                                                  |
| 20-26                                    | Silty clay, gray                              | slightly moist to 25', very moist at 25'             |
| 26-27'                                   | Sandstone, dark gray, medium to fine grained  | Making 1/2 - 1/4 gpm water                           |
| 27-31'                                   | Silty clay, gray                              | slightly moist                                       |
|                                          |                                               |                                                      |
|                                          |                                               |                                                      |
|                                          |                                               |                                                      |
|                                          |                                               |                                                      |
|                                          |                                               |                                                      |



## MONITORING WELL LITHOLOGIC AND COMPLETION LOG

JOB NO.: 89-3020.L

PROJECT: Big Timber Landfill STATE: MT COUNTY: Sweetgrass WELL NO.: BT-6

|                             |            |                                             |
|-----------------------------|------------|---------------------------------------------|
| LEGAL LOCATION: T1N R15E S8 | TRACT ABDD | DESCRIPTIVE LOCATION: 500 feet west of BT-1 |
|-----------------------------|------------|---------------------------------------------|

DATE DATE DRILLING COMPANY/  
STARTED: 7/19/90 COMPLETED: 7/19/90 DRILLER: ESD/Ed Hillman LOGGED BY: D. Hazen

DRILLING BOREHOLE  
METHOD: Rotary DIAMETER (in): 5 7/8 DRILL FLUIDS USED: Air

|                                  |                                |                                          |                        |                                                 |
|----------------------------------|--------------------------------|------------------------------------------|------------------------|-------------------------------------------------|
| TOTAL DEPTH<br>DRILLED (ft): 37' | TOTAL DEPTH<br>CASED (ft): 25' | INTERVAL PERFORATED<br>OR SCREENED (ft): | from: 25.0<br>to: 30.0 | DIAMETER AND 2" PVC, Sch. 40<br>TYPE OF CASING: |
|----------------------------------|--------------------------------|------------------------------------------|------------------------|-------------------------------------------------|

|                        |                                                                         |                                    |                                     |                                     |
|------------------------|-------------------------------------------------------------------------|------------------------------------|-------------------------------------|-------------------------------------|
| METHOD OF PERFORATION: | <input type="checkbox"/> Open Hole                                      | DURING WELL CONSTRUCTION WAS/WERE: |                                     |                                     |
|                        | <input type="checkbox"/> Open Bottom                                    |                                    | YES                                 | NO                                  |
|                        | <input type="checkbox"/> Saw Slotted                                    | WELL DEVELOPED                     | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
|                        | <input checked="" type="checkbox"/> Mechanical Slots 0.020 _____ (size) | WELL PUMPED                        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
|                        | <input type="checkbox"/> OTHER (specify) _____                          | WATER SAMPLES COLLECTED            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
|                        |                                                                         | MATERIAL SAMPLES COLLECTED         | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |

ANNULAR COMPLETION CHARACTERISTICS

|                                                     |                                                                                 |
|-----------------------------------------------------|---------------------------------------------------------------------------------|
| WELL PROTECTOR: Length <u>10 ft</u> Diam. <u>6"</u> | SURFACE SEAL: Type: <u>Concrete</u> from: <u>0</u> to: <u>0.5 ft</u>            |
| LOCK NO.: <u>2265</u>                               | BACKFILL: Material: <u>Bentonite</u> from: <u>6'</u> to: <u>23'</u>             |
|                                                     | FILTER PACK: Type: <u>10-20 silica sand</u> from: <u>23 ft</u> to: <u>33 ft</u> |

|                              |                                  |                                                                                |                                                           |
|------------------------------|----------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------|
| STATIC WATER<br>LEVEL: 22.85 | MEASURING POINT<br>DATE: 7/20/90 | DESCRIPTION/<br>ELEVATION: Top of Steel Well Protector, N side at mark, 4057.5 | MEASURING POINT RELATIVE TO<br>GROUND SURFACE (+/-): +2.3 |
|------------------------------|----------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------|

REMARKS: 7.7' of 6" steel in ground

[illegible]



DATA SET: 21-3

CLIENT: City of Big Spring  
 LOCATION: Big Tank, AT  
 COUNTY: Brewster County  
 OBJECT: Well Slug Test Data  
 AQUIFER: Confined  
 INITIAL HEAD: 0.250 ft  
 STABIL. TIME: 21.000 ft  
 INITIAL HEAD: 2.170 ft

DATE: 11/1/87  
 WELL DEPTH: 20.00 ft  
 WATER LEVEL: 15.70 ft  
 PUMPING RATE: 0.00 ft  
 SCREEN SIZE: 10.00 ft  
 TRANS. COEFF: 1.0000

FITTING ERROR: 15.715 PERCENT

MODEL PARAMETERS:

STORAGE COEFF.: 0.0010000 PAGE

TRANSMISSIVITY: 0.06354 square ft/sec PAGE

MODEL TYPE: UNSTEADY-AQUIFER (Cooper et al.)

| No. | TIME<br>(secs) | Head, h (ft) |        | DIFFERENCE<br>(percent) |
|-----|----------------|--------------|--------|-------------------------|
|     |                | DATA         | MODEL  |                         |
| 1   | 0.100          | 3.17         | 3.12   | 0.156                   |
| 2   | 0.20           | 3.17         | 3.12   | 0.156                   |
| 3   | 1.00           | 3.17         | 3.12   | 0.156                   |
| 4   | 25.00          | 3.23         | 3.20   | -0.09                   |
| 5   | 51.00          | 3.02         | 3.04   | 0.66                    |
| 6   | 55.00          | 2.84         | 2.82   | -0.71                   |
| 7   | 75.00          | 2.69         | 2.72   | 1.12                    |
| 8   | 105.0          | 2.30         | 2.29   | -0.43                   |
| 9   | 130.0          | 2.02         | 2.00   | -0.99                   |
| 10  | 200.0          | 1.57         | 1.48   | -5.73                   |
| 11  | 271.0          | 1.21         | 1.25   | 3.31                    |
| 12  | 343.0          | 0.870        | 0.743  | -14.97                  |
| 13  | 414.0          | 0.500        | 0.481  | -3.80                   |
| 14  | 486.0          | 0.250        | 0.282  | 12.80                   |
| 15  | 560.0          | 0.0700       | 0.0635 | -9.29                   |

## APPENDIX B

### SLUG TEST DATA AND ANALYSIS PLOTS

Chen, Northern



## DATA SET: BT-5

|                |                     |                |           |
|----------------|---------------------|----------------|-----------|
| CLIENT:        | City of Big Timber  | DATE:          | 7/20/90   |
| LOCATION:      | Big Timber, MT      | WELL NO.:      | BT-5      |
| COUNTY:        | Sweetgrass County   | WELL DEPTH:    | 30.00 ft  |
| PROJECT:       | Well Slug Test Data | WATER TABLE:   | 15.750 ft |
| AQUIFER:       | Confined            | THICKNESS:     | 9.00 ft   |
| INTAKE RADIUS: | 0.250 ft            | CASING RADIUS: | 0.083 ft  |
| SCREEN TOP:    | 21.000 ft           | SCREEN BASE:   | 30.00 ft  |
| INITIAL HEAD:  | 5.170 ft            | TRANS. RATIO:  | 1.0000    |

FITTING ERROR: 15.735 PERCENT

## MODEL PARAMETERS:

STORAGE COEFF.: 0.0010837 FREE

TRANSMISSIVITY: 0.06554 square cm/sec FREE

MODEL TYPE: CONFINED AQUIFER (Cooper et al.)

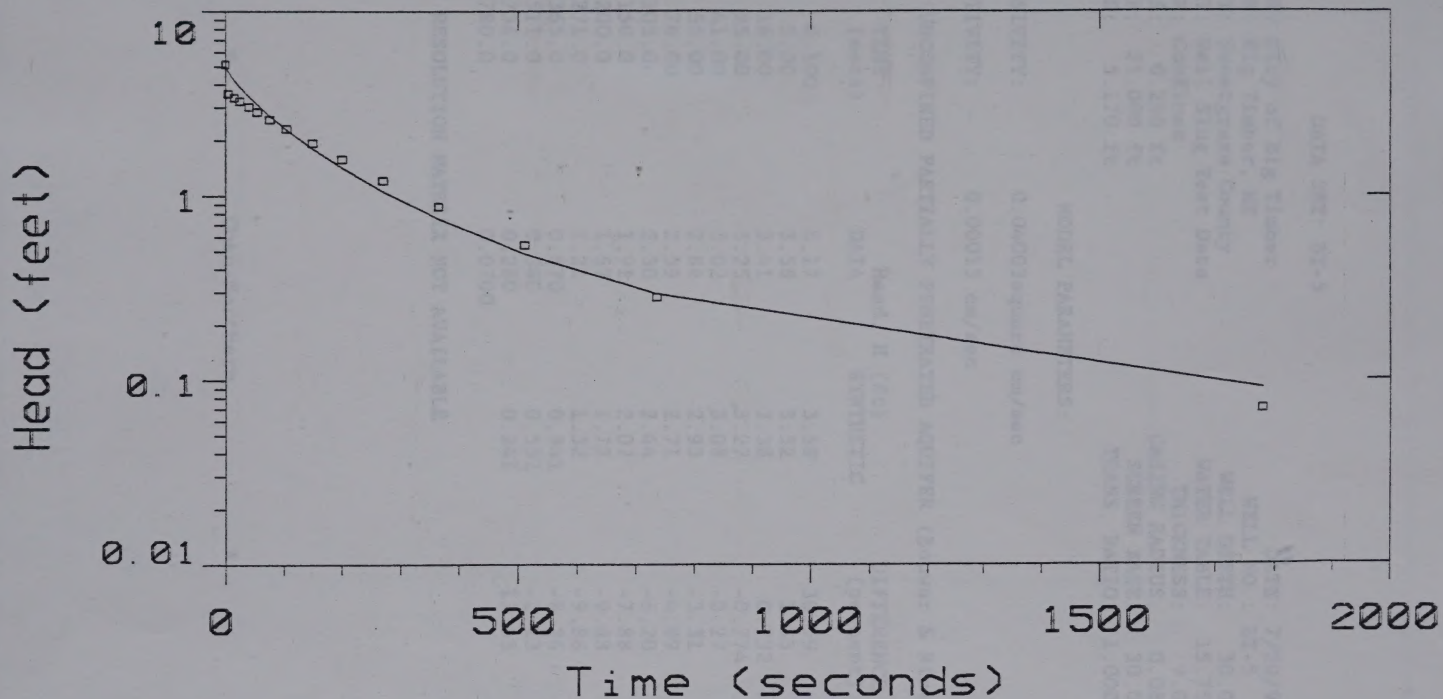
| No. | TIME<br>(secs) | Head, H (ft) |           | DIFFERENCE<br>(percent) |
|-----|----------------|--------------|-----------|-------------------------|
|     |                | DATA         | SYNTHETIC |                         |
| 1   | 0.100          | 5.17         | 5.12      | 0.799                   |
| 2   | 5.00           | 3.58         | 4.72      | -32.04                  |
| 3   | 16.00          | 3.41         | 4.21      | -23.72                  |
| 4   | 25.00          | 3.25         | 3.90      | -20.07                  |
| 5   | 41.00          | 3.02         | 3.44      | -14.16                  |
| 6   | 55.00          | 2.84         | 3.12      | -10.01                  |
| 7   | 76.00          | 2.59         | 2.72      | -5.26                   |
| 8   | 105.0          | 2.30         | 2.29      | 0.200                   |
| 9   | 150.0          | 1.92         | 1.80      | 6.00                    |
| 10  | 200.0          | 1.57         | 1.42      | 9.50                    |
| 11  | 271.0          | 1.21         | 1.05      | 12.94                   |
| 12  | 365.0          | 0.870        | 0.748     | 13.97                   |
| 13  | 511.0          | 0.540        | 0.483     | 10.38                   |
| 14  | 736.0          | 0.280        | 0.292     | -4.45                   |
| 15  | 1780.0         | 0.0700       | 0.0903    | -29.09                  |

\*

Chen-Northern

\*





MODEL TYPE: COOPER et al.

TRANSMISSIVITY: .06554 sq. cm/sec

STORATIVITY: .001083

INITIAL HEAD: 5.170 ft

Data Set: BT-5

Date: 7/20/90

for: City of Big Timber

by: Chen-Northern

WELL DATA: Units: ft

AQUIFER: Confined

THICKNESS: 9.000

SCREEN: top: 21.00 base: 30.00

DIAMETER: casing: .1666 intake: .5000

DEPTH: Water Table: 15.75 TD: 30.00

Well Slug Test Data

Well: BT-5  
Big Timber, MT  
Sweetgrass County



## DATA SET: BT-5

|                              |                         |
|------------------------------|-------------------------|
| CLIENT: City of Big Timber   | DATE: 7/20/90           |
| LOCATION: Big Timber, MT     | WELL NO.: BT-5          |
| COUNTY: Sweetgrass County    | WELL DEPTH: 30.00 ft    |
| PROJECT: Well Slug Test Data | WATER TABLE: 15.750 ft  |
| AQUIFER: Confined            | THICKNESS: 9.00 ft      |
| INTAKE RADIUS: 0.250 ft      | CASING RADIUS: 0.083 ft |
| SCREEN TOP: 21.000 ft        | SCREEN BASE: 30.00 ft   |
| INITIAL HEAD: 5.170 ft       | TRANS. RATIO: 1.0000    |

## MODEL PARAMETERS:

TRANSMISSIVITY: 0.04003square cm/sec

CONDUCTIVITY: 0.00015 cm/sec

MODEL TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer &amp; Rice)

| No. | TIME<br>(secs) | Head, H (ft)<br>DATA | SYNTHETIC | DIFFERENCE<br>(percent) |
|-----|----------------|----------------------|-----------|-------------------------|
| 1   | 0.100          | 5.17                 | 3.58      | 30.59                   |
| 2   | 5.00           | 3.58                 | 3.52      | 1.55                    |
| 3   | 16.00          | 3.41                 | 3.38      | 0.732                   |
| 4   | 25.00          | 3.25                 | 3.27      | -0.774                  |
| 5   | 41.00          | 3.02                 | 3.08      | -2.27                   |
| 6   | 55.00          | 2.84                 | 2.93      | -3.31                   |
| 7   | 76.00          | 2.59                 | 2.71      | -4.89                   |
| 8   | 105.0          | 2.30                 | 2.44      | -6.20                   |
| 9   | 150.0          | 1.92                 | 2.07      | -7.88                   |
| 10  | 200.0          | 1.57                 | 1.72      | -9.83                   |
| 11  | 271.0          | 1.21                 | 1.32      | -9.86                   |
| 12  | 365.0          | 0.870                | 0.941     | -8.26                   |
| 13  | 511.0          | 0.540                | 0.551     | -2.13                   |
| 14  | 736.0          | 0.280                | 0.241     | 13.65                   |
| 15  | 1780.0         | 0.0700               |           |                         |

CURRENT RESOLUTION MATRIIX NOT AVAILABLE

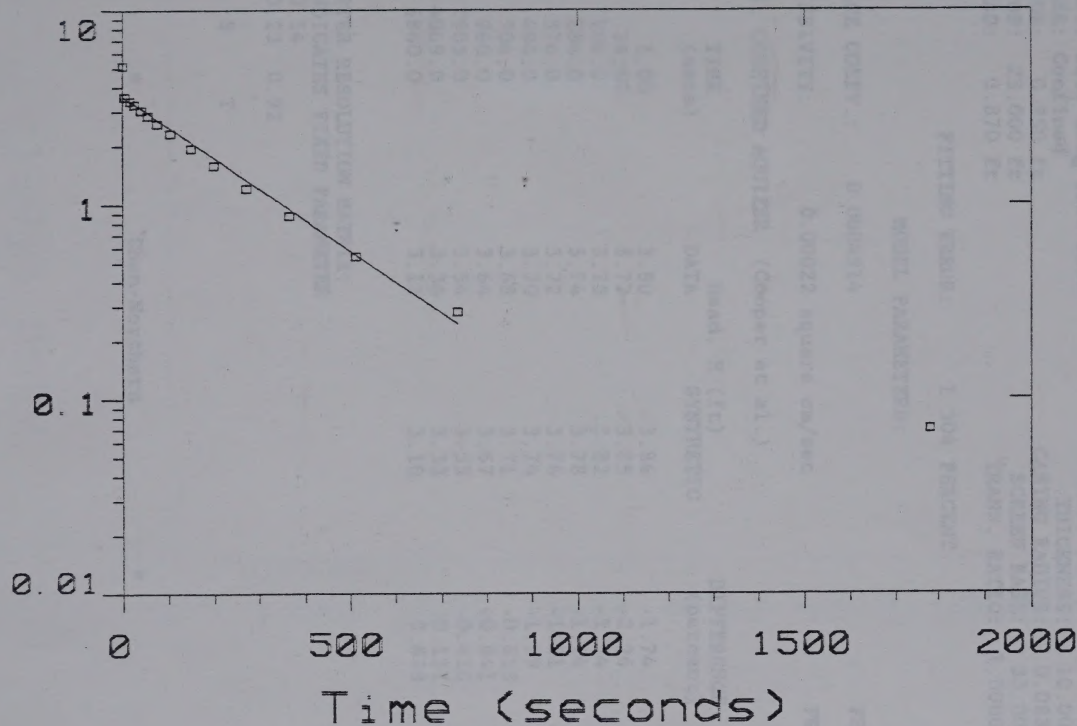
\*

Chen-Northern

\*



Head (feet)



MODEL TYPE: BOUWER and RICE

CONDUCTIVITY: .0001459 cm/sec

TRANSMISSIVITY: .04002 sq. cm/sec

INITIAL HEAD: 5.170 ft

Data Set: BT-5

Date: 7/20/90

for: City of Big Timber

by: Chen-Northern

WELL DATA: Units: ft

AQUIFER: Confined

THICKNESS: 9.000

SCREEN: top: 21.00 base: 30.00

DIAMETER: casing: .1666 intake: .5000

DEPTH: Water Table: 15.75 TD: 30.00

Well Slug Test Data

Well: BT-5

Big Timber, MT

Sweetgrass County



## DATA SET: BT-6

|                              |                         |
|------------------------------|-------------------------|
| CLIENT: City of Big Timber   | DATE: 7/20/90           |
| LOCATION: Big Timber, MT     | WELL NO.: BT-6          |
| COUNTY: Sweetgrass County    | WELL DEPTH: 33.00 ft    |
| PROJECT: Well Slug Test Data | WATER TABLE: 20.550 ft  |
| AQUIFER: Confined            | THICKNESS: 10.00 ft     |
| INTAKE RADIUS: 0.250 ft      | CASING RADIUS: 0.083 ft |
| SCREEN TOP: 23.000 ft        | SCREEN BASE: 33.00 ft   |
| INITIAL HEAD: 3.870 ft       | TRANS. RATIO: 1.0000    |

FITTING ERROR: 1.304 PERCENT

## MODEL PARAMETERS:

STORAGE COEFF.: 0.0004914 FREE

TRANSMISSIVITY: 0.00022 square cm/sec FREE

MODEL TYPE: CONFINED AQUIFER (Cooper et al.)

| No. | TIME<br>(secs) | Head, H (ft) |           | DIFFERENCE<br>(percent) |
|-----|----------------|--------------|-----------|-------------------------|
|     |                | DATA         | SYNTHETIC |                         |
| 1   | 1.00           | 3.80         | 3.86      | -1.74                   |
| 2   | 14.00          | 3.77         | 3.85      | -2.26                   |
| 3   | 104.0          | 3.75         | 3.82      | -1.94                   |
| 4   | 284.0          | 3.74         | 3.78      | -1.14                   |
| 5   | 374.0          | 3.72         | 3.76      | -1.21                   |
| 6   | 494.0          | 3.70         | 3.74      | -1.19                   |
| 7   | 704.0          | 3.68         | 3.71      | -0.853                  |
| 8   | 960.0          | 3.64         | 3.67      | -0.941                  |
| 9   | 1905.0         | 3.54         | 3.55      | -0.416                  |
| 10  | 4069.0         | 3.34         | 3.33      | 0.131                   |
| 11  | 6860.0         | 3.13         | 3.10      | 0.878                   |

## PARAMETER RESOLUTION MATRIX:

"\*" INDICATES FIXED PARAMETER

S 0.14  
T 0.23 0.92

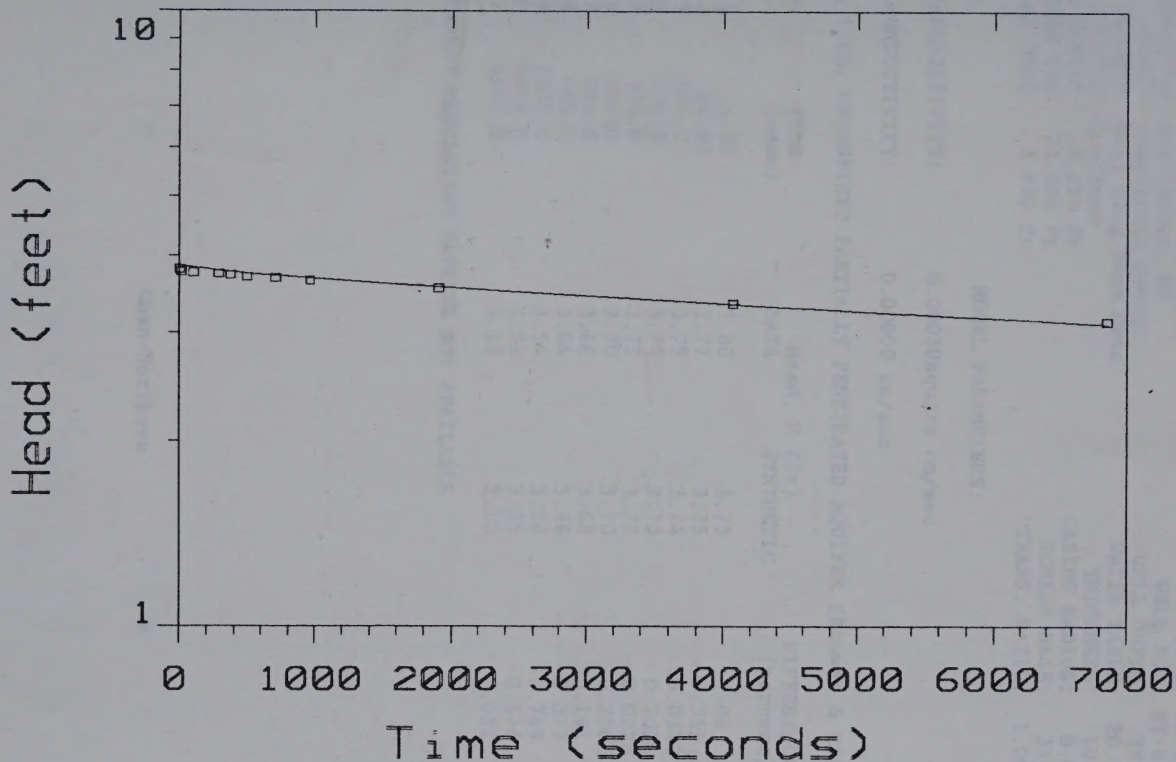
S T

\*

Chen-Northern

\*





MODEL TYPE: COOPER et al.

TRANSMISSIVITY: .0002169 sq. cm/sec

STORATIVITY: .0004913

INITIAL HEAD: 3.870 ft

Data Set: BT-6

Date: 7/20/90

for: City of Big Timber

by: Chen-Northern

WELL DATA: Units: ft

AQUIFER: Confined

THICKNESS: 10.00

SCREEN: top: 23.00 base: 33.00

DIAMETER: casing: .1666 intake: .5000

DEPTH: Water Table: 20.55 TD: 33.00

Well Slug Test Data

Well: BT-6

Big Timber, MT

Sweetgrass County



## DATA SET: BT-6

|                              |                         |
|------------------------------|-------------------------|
| CLIENT: City of Big Timber   | DATE: 7/20/90           |
| LOCATION: Big Timber, MT     | WELL NO.: BT-6          |
| COUNTY: Sweetgrass County    | WELL DEPTH: 33.00 ft    |
| PROJECT: Well Slug Test Data | WATER TABLE: 20.550 ft  |
| AQUIFER: Confined            | THICKNESS: 10.00 ft     |
| INTAKE RADIUS: 0.250 ft      | CASING RADIUS: 0.083 ft |
| SCREEN TOP: 23.000 ft        | SCREEN BASE: 33.00 ft   |
| INITIAL HEAD: 3.870 ft       | TRANS. RATIO: 1.0000    |

## MODEL PARAMETERS:

TRANSMISSIVITY: 0.00030square cm/sec

CONDUCTIVITY: 0.00000 cm/sec

MODEL TYPE: UNCONFINED PARTIALLY PENETRATED AQUIFER (Bouwer &amp; Rice)

| No. | TIME<br>(secs) | Head, H (ft) |           | DIFFERENCE<br>(percent) |
|-----|----------------|--------------|-----------|-------------------------|
|     |                | DATA         | SYNTHETIC |                         |
| 1   | 1.00           | 3.80         | 3.75      | 1.06                    |
| 2   | 14.00          | 3.77         | 3.75      | 0.315                   |
| 3   | 104.0          | 3.75         | 3.74      | 0.0332                  |
| 4   | 284.0          | 3.74         | 3.73      | 0.263                   |
| 5   | 374.0          | 3.72         | 3.72      | -0.0228                 |
| 6   | 494.0          | 3.70         | 3.70      | -0.230                  |
| 7   | 704.0          | 3.68         | 3.68      | -0.191                  |
| 8   | 960.0          | 3.64         | 3.66      | -0.577                  |
| 9   | 1905.0         | 3.54         | 3.56      | -0.749                  |
| 10  | 4069.0         | 3.34         | 3.35      | -0.576                  |
| 11  | 6860.0         | 3.13         | 3.10      | 0.651                   |

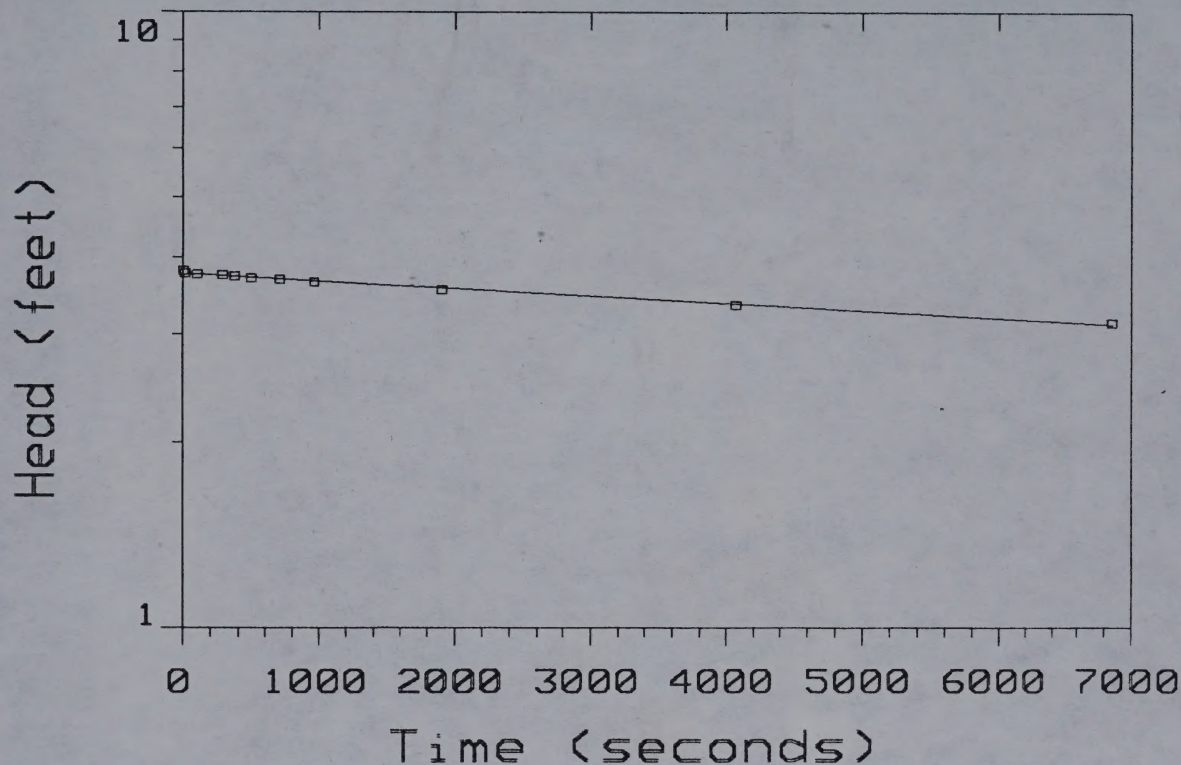
CURRENT RESOLUTION MATRIIX NOT AVAILABLE

\*

Chen-Northern

\*





|                                     |  |                                       |                                                   |
|-------------------------------------|--|---------------------------------------|---------------------------------------------------|
| MODEL TYPE: BOUWER and RICE         |  | for: City of Big Timber               | Well Slug Test Data                               |
| CONDUCTIVITY: 9.870E-7 cm/sec       |  | by: Chen-Northern                     |                                                   |
| TRANSMISSIVITY: .0003008 sq. cm/sec |  | WELL DATA: Units: ft                  | Well: BT-6<br>Big Timber, MT<br>Sweetgrass County |
| INITIAL HEAD: 3.870 ft              |  | AQUIFER: Confined                     |                                                   |
| Data Set: BT-6                      |  | THICKNESS: 10.00                      |                                                   |
| Date: 7/20/90                       |  | SCREEN: top: 23.00 base: 33.00        |                                                   |
|                                     |  | DIAMETER: casing: .1666 intake: .5000 |                                                   |
|                                     |  | DEPTH: Water Table: 20.55 TD: 33.00   |                                                   |

